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Determination of Use of Some Natural Plant Species in Vertical Garden Systems in İzmir Region*

İzmir Yöresindeki Bazı Doğal Bitki Türlerinin Dikey Bahçe Sistemlerinde Kullanımlarının Belirlenmesi

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Abstract

Migration to urban areas in the world triggers the urban population, construction and use of natural resources. This situation negatively affects the urban biodiversity, the sustainability of the city and the ecology of the city. Especially with the increase in construction, urban open-green areas and natural vegetation, which are important assets of the city, are adversely affected. This study aimed to quantitatively determine the availability of natural plant species in vertical garden systems, which were a good alternative for creating urban open-green spaces. The city of Izmir, one of the important metropolitan cities of Turkey, was chosen as the study area. With the literature review, species that naturally grow in the Izmir region and suitable for use in landscape studies were determined. Multi-criteria decision-making methods such as Analytical Hierarchy Process (AHP) and Ranking of Preferences According to Ideal Similarity (TOPSIS) methods were used to determine the type that could be used in vertical garden systems among these determined species. In the AHP method, the selection criteria were determined and the consistency analysis was performed by calculating the criteria weights. As a result of the consistency of the criteria (0.091314782), the AHP method was completed and the TOPSIS method was applied and the species were ranked starting from the most suitable. As a result; *Lavandula stoechas* L. was quantitatively determined as the most suitable species for use in vertical garden systems, with an evaluation score of 0.887765025.

Keywords: Vertical garden, urban biodiversity, AHP, TOPSIS, native plants

Özet

Dünyada kentsel alanlara göç, kentsel nüfusu, yapılaşmayı ve doğal kaynakların kullanımını tetiklemektedir. Bu durum kentsel biyoçeşitliliği, kentin sürdürülebilirliğini ve kentin ekolojisini olumsuz etkilemektedir. Özellikle yapılaşmanın artmasıyla birlikte kentin önemli varlıkları olan kentsel açık-yeşil alanlar ve doğal bitki örtüsü olumsuz etkilenmektedir. Bu çalışma, kentsel açık-yeşil alanlar oluşturmada iyi bir alternatif olan dikey bahçe sistemlerinde doğal bitki türlerinin kullanılabilirliğini nicel olarak belirlemeyi amaçlamıştır. Çalışma alanı olarak Türkiye'nin önemli metropol şehirlerinden biri olan İzmir şehri seçilmiştir. Literatür taraması ile İzmir yöresinde doğal olarak yetişen ve peyzaj çalışmalarında kullanıma uygun türler belirlenmiştir. Belirlenen bu türler içerisinden dikey bahçe sistemlerinde kullanılabilecek türü belirlemede çok kriterli karar verme yöntemleri olan, Analitik Hiyerarşi Prosesi (AHP) ve İdeale Benzerliğe Göre Tercih Sıralaması Yöntemi (TOPSIS) yöntemleri kullanılmıştır. AHP yönteminde seçim kriterleri belirlenmiş ve kriter ağırlıkları hesaplanarak tutarlılık analizi yapılmıştır. Kriterlerin tutarlı olması sonucunda (0.091314782) AHP yöntemi tamamlanıp TOPSIS yöntemi uygulanmış ve türler en uygun olandan başlanarak sıralanmıştır. Sonuç olarak; *Lavandula stoechas* L., 0.887765025 değerlendirme puanı alarak kantitatif olarak dikey bahçe sistemlerinde kullanıma en uygun tür olarak belirlenmiştir.

Anahtar Kelimeler: Dikey bahçe, kentsel biyoçeşitlilik, AHP, TOPSIS, doğal bitki türleri

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1. Introduction

With the migration from rural areas to urban areas, the urban population is gradually increasing. Depending on the population growth, the need for shelter and energy is parallel to this situation. This situation directly triggers urban construction and the use of natural resources in energy (Wang et al., 2016). These interactions that occur in urban areas around the world cause a decrease in open-green spaces in cities, urban sustainability is deteriorated and many environmental problems arise accordingly. Reducing urban open-green spaces. The increase in the urban heat island effect causes environmental problems such as air, visual and noise pollution. In addition, urban biodiversity and sustainability are negatively affected by the decrease in open-green areas (Davis et al., 2017). The natural vegetation of the cities is one of the most important structures of the urban biodiversity and the identity of the city (Asaduzzaman and Sadat 2020; Gür and Kahraman 2022). According to Eroğlu and Acar (2009), the protection of natural vegetation in cities and its use in landscape studies are very important in terms of urban biodiversity and sustainability. However, the decrease in the open-green areas in cities and the fact that they are in danger of extinction do not make it possible to use these species in landscape studies because the necessary areas cannot be provided. For this reason, the importance of alternative open-green spaces in cities is gradually increasing. Vertical garden systems are one of the methods applied to create alternative green spaces in urban areas such as roof gardens (Belcher et al., 2018; Charoenkit and Yiemwattana 2021). Vertical garden systems, which are used in a wide variety of indoor and outdoor spaces, are based on the principle of growing the plant material in a vertical position integrated with the building surface and in a limited area (Perini et al., 2013). Vertical garden systems are divided into various types according to the way of application and the difference in the material used. Modular panel systems, systems created using felt and hydroponic systems are vertical garden application methods. Metal fence systems also known as "living walls" can be considered a vertical garden systems. Unlike other systems, the plants take their nutrients directly from the soil in these systems (Figure 1) (Natarajan et al., 2015; Bustami et al., 2018).

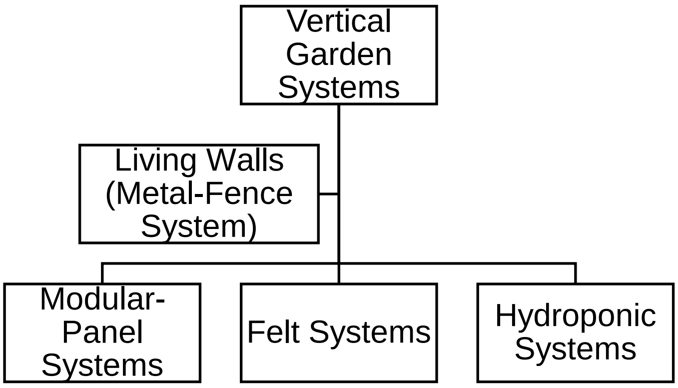

Figure 1. Vertical garden systems.

Determining the plant species to be used in vertical garden systems is very important as in horizontal plane applications. Natural plant species, whose use is limited due to decreasing green areas, may have a very high number of alternatives for use in vertical garden systems (Gür, 2021). By using scientific methods based on numerical data in determining those alternative species that can be used in vertical garden systems, both a more accurate decision-making process is created and the sustainability and functionality of the systems are established on a more solid basis (Hosseini et al., 2021). Decision-making problems arise when there are disagreements on different issues at different stages of our lives. Decision-making is generally the process of choosing one or more of the most appropriate options from various alternatives, depending on a purpose and based on certain criteria. In this process, Multi-Criteria Decision Making (MCD) methods, which are based on pairwise comparisons of certain criteria to reach the most accurate decision, assist the process with numerical data (Gür et al., 2017a). Multi-criteria decision-making methods are quantitative methods that have more than one alternative and help decision-makers transform their decision-making processes into quantitative evaluations and help qualitative observations to remove uncertainties (Santoso and Darsono 2019; Singh et al., 2022). According to the similarity to the ideal solution, the order of preference technique (TOPSIS) and the analytical hierarchy method (AHP) are two of the multi-criteria decision-making methods. These two methods can be used together in determination processes with many alternatives. The weight values of the criteria, whose hierarchy is created in the AHP method and whose consistency analysis is performed, are used to rank the alternatives from the most ideal to the non-ideal in the TOPSIS method. This is how the two methods are used together (Namin et al., 2022). In the literature, these two multi-criteria decision-making methods have been used on very different and various decision-making problems.

Geyik et al. (2016) emphasized that choosing the right publishing house for the publication of an author's work can provide high income at a low cost. In the study, they used the AHP and TOPSIS methods together to solve this problem. In the AHP method, they created the hierarchical structure of the publishing house selection criteria, calculated the weight values and made the consistency analysis. Then, using the weight values of these criteria, they used the TOPSIS method to determine the most ideal among 6 publishing house alternatives. Ak Oğuz and Köksal (2018) mentioned the importance of choosing the best supplier and creating the most suitable conditions in the process of creating the supply chain in public procurement. In their studies, they used AHP and TOPSIS methods to solve this problem. Accordingly, in the AHP method, they created the hierarchical structure of the publishing house selection criteria, calculated the weight values and made the consistency analysis. Then, using the TOPSIS method, they determined the most suitable one among 5 different supplier alternatives. Alakas et al. (2019) mentioned in their studies that it is very important to train patients for treatment in the most urgent way possible, as well as correct and good treatment in accidents and diseases that occur in daily life. They stated that the problem that occurs to provide the best service in this area is the problem of multi-criteria decision-making. As a method, they used AHP, TOPSIS and VIKOR methods in their studies. As a result of the AHP-TOPSIS methods, the best alternative is EMS; As a result of the AHP-VIKOR methods, EMS and DORSER have revealed that one of the companies is the best alternative. Vural et al. (2019) talked about the importance of helping individuals who need help in their work and the fair distribution of income within the social state structure. In their study, they stated that the objective determination of people with this status is a multi-criteria decision-making problem. As a method, they used AHP and TOPSIS methods together to solve this problem. Doğan and Borat (2021) focused on the selection problems of desktop computers to be procured for use in a public institution in the province of Isparta. They used AHP and TOPSIS methods together to solve the problem. They determined 6 different criteria for selection and compared these criteria in binary matrices in the AHP method, calculated the weight values of the criteria and made consistency analyses. Then, they ranked the alternatives from the most ideal to the most ideal.

This study was carried out to determine the plant species that can be used in vertical garden systems among the plant species that spread naturally in the Izmir Region.

2. Material and Method

It was aimed to rank the alternatives and to determine the most suitable species by making evaluations according to various criteria among 56 different plant species alternatives.

In this direction, the criteria affecting the problem were determined by taking the geometric average of the expert opinions received from five authorized people who have made applications related to the literature and vertical garden systems. By using the AHP method, the hierarchical structure of the criteria was created, the weight values were calculated and consistency analyses were made. By using the weights obtained by the AHP method, the alternatives were evaluated in the TOPSIS method, the suitable alternatives were listed and the most suitable species in the ranking was determined.

The AHP method is one of the multi-criteria decision-making methods, and this method, developed by Thomas L. Saaty in the 1970s, is a mathematical model that facilitates making the necessary decisions during the selection stages (Ludwig and Iannuzzi, 2006). The AHP method consists of 4 stages (Zaini et al., 2015; Chaipetch et al., 2022; Maidin et al., 2022).

Stage 1: Determining the definition of the problem and creating the structure of the problem by the decision makers: In this step, the problem to be decided is handled and the criteria that are effective on the problem and in the decision-making process are determined. After the criteria are determined, a hierarchical structure is created.

Stage 2: Formation of the pairwise comparison matrix and normalization of the comparison matrix: After the criteria are determined, pairwise comparison matrices are created to evaluate them relative to each other. In this matrix structure, Saaty's 1-9 scale is used while each criterion is evaluated according to another criterion. Table 1 shows the scale used during the evaluation.

Table 1. Saaty's scale of 1-9 (Fawad et al., 2022).

Importance Level	Definition	Explanation
1	Equally Important	Both factors are equally important
3	Moderately Important	One factor is slightly more important than the other factor
5	Strongly Important	One factor is strongly more important than the other factor
7	Very Strongly Important	One factor is very strongly more important than the other factor
9	Extremely Important	One factor is extremely strong more important than the other factor
2,4,6,8	Intermediate Values	It is used when there are small differences between two factors.
Mutual values	If a value x is assigned when comparing i,j; The value to be assigned when comparing with i should be 1/x.	

This scale is used to indicate the dominance or importance of criteria in the comparison matrix. The “i” and “j” values indicated in Table 1 represent the criteria. The “x” value indicates the superiority value given among the criteria on the 1-9 scale. When the two criteria are compared, the "x" superiority value given is in a symmetrical structure and the division value of the 1/x part is written (Aydın et al., 2009). After the evaluation of the criteria, these values are normalized and the normalized matrix is obtained. Equation 1 is used to obtain the normalized matrix. According to Equation 1, the sum of the values of each column is found separately. Normalization is performed by dividing the value in each column by the total value of the column to which it belongs.

$$b_{ij} = \frac{a_{ij}}{\sum_{i=1}^{n} a_{ij}} \quad (1)$$

<u>Stage 3:</u> Determining the eigenvectors of the criteria: At this stage, the weights of the criteria are calculated by averaging the row sums of the normalized matrices. This step is done with the help of Equation 2.

$$wi = \frac{\sum_{j=1}^{n} cij}{n} \quad (2)$$

According to Equation 2, the value of each row is added separately and divided by the number of criteria to get the weight of the criteria. The “n” value in the equation is equal to the number of criteria.

<u>Stage 4:</u> Performing the consistency analysis: Finally, the consistency ratio is calculated, which shows that the evaluations made are correct. It is desired that this ratio be lower than 0.1 (Malul and Bar-El, 2009).

TOPSIS method is a multi-criteria decision making method developed by Ching-Lai Hwang and Kwangsun Yoon in 1981. Attributes, objectives and criteria are the basic principles of the method. The TOPSIS method consists of 6 stages (Kiliç and Kaya, 2016; Nabizadeh et al., 2021).

<u>Stage 1:</u> Decision matrix is created: The evaluation in the decision matrix is evaluated using certain score ranges. While preparing the decision matrix structure, the determined score ranges are scored according to each criterion, as in the AHP method. The higher the importance, the higher the point value.

Stage 2: Normalization operations of the decision matrix are made: After the decision matrix structure, the standard decision matrix is created in this step. Normalization is done in the standard decision matrix. Equation 3 is used for this operation.

$$r_{ij} = \frac{a_{ij}}{\sqrt{\sum_{i=1}^{m} a_{ij}^2}} \ , i = 1,2, \ldots, m; j = 1,2, \ldots, n \quad (3)$$

Stage 3: Normalized decision matrix elements are weighted according to the importance of the criteria: The standard decision matrix is converted to a weighted standard decision matrix. For this, the weights obtained from the AHP method are used. The weighted decision matrix is obtained by multiplying the value under each criterion by the weight of that criterion.

Stage 4: Ideal points are determined: Negative ideal and positive ideal solution points are created using the weighted standard decision matrix structure. Equation-4 and Equation-5 are used for this operation.

$$A^* = \{(\max i \ v_{ij} \ | j \in J), (\min i \ v_{ij} \ | j \in J)\}, A^* = \{v_1^*, v_2^*, \ldots, v_n^*\} \quad (4)$$

$$A^- = \{(\min i \ v_{ij} \ | j \in J), (\max i \ v_{ij} \ | j \in J^\iota)\}, A^- = \{v_1^-, v_2^-, \ldots, v_n^-\} \quad (5)$$

At this stage, the positive ideal solution point is calculated with Equation-4, and the negative ideal solution point is calculated with Equation-5.

Stage 5: Calculating the maximum distance to the ideal point: In this step, Equation-6 and Equation 7 are used to calculate the closest and farthest distance to the ideal point. These equations give us the maximum distances. Equation 6 is used for the closest distance, Equation 7 is used for the farthest distance.

$$S_i^* = \sqrt{\sum_{j=1}^{n} (v_{ij} - v_j^*)} \quad (6)$$

$$S_i^- = \sqrt{\sum_{j=1}^{n} (v_{ij} - v_j^-)} \quad (7)$$

Stage 6: The distance to the ideal point is calculated: In this step, which is the last step of the TOPSIS method, the relative proximity to the ideal solution is calculated and the alternative plants are ranked. Equation-8 is used for this step.

$$C_i^* = \frac{s_i^-}{s_i^- + s_i^*} \ , 0 \leq C_i^* \leq 1 \quad (8)$$

The use of AHP and TOPSIS methods together defines the problem to be solved in a measured way and provides convenience in reaching a solution (Bathrinath et al., 2020). In general, using the two methods together can progress within a certain flow (Figure 2) (Gür et al., 2017b).

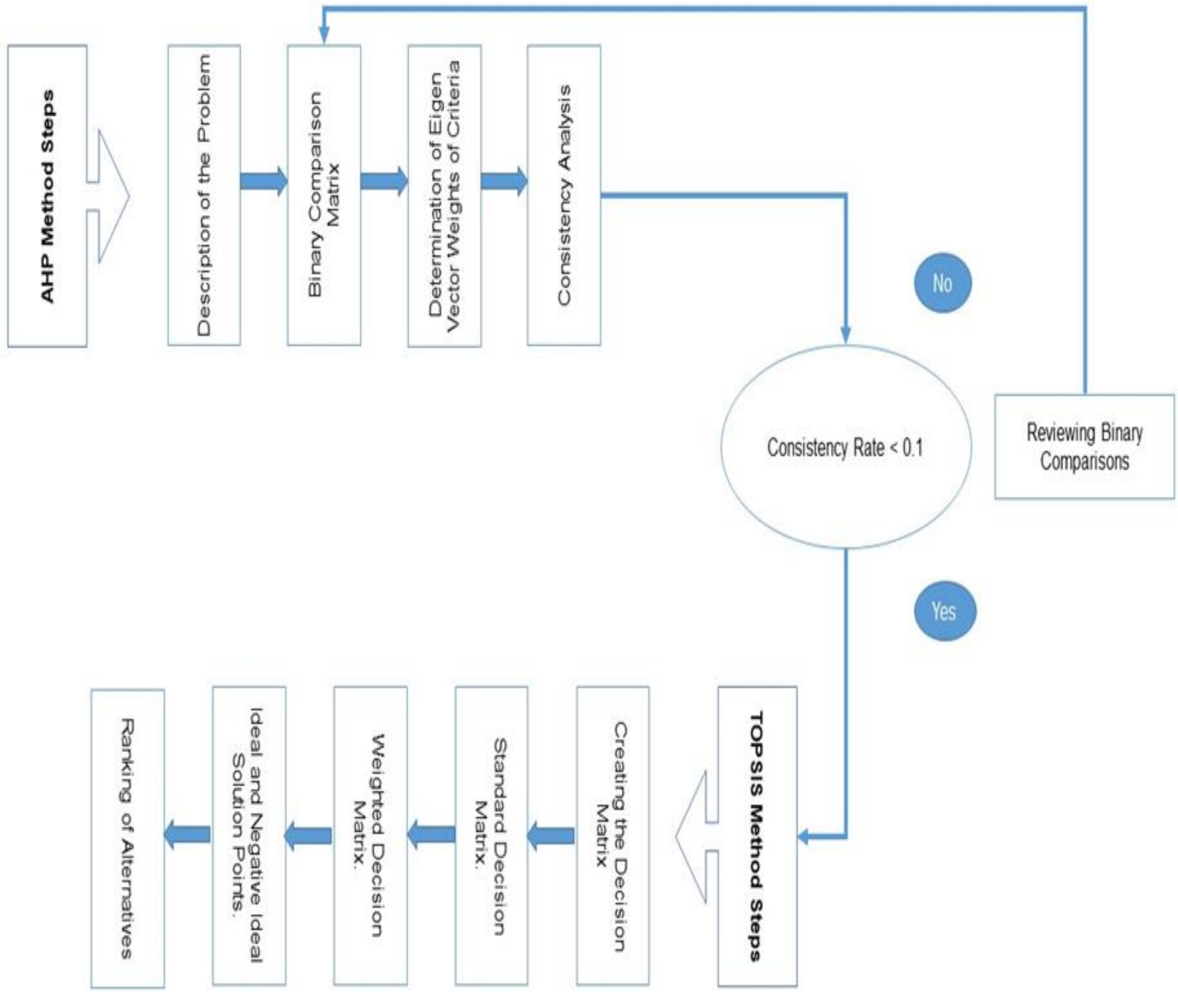

Figure 2. Application flow chart of AHP and TOPSIS methods.

The plant species constituting the main material of the study were chosen randomly, regardless of whether they are shrubs, trees, shrubs and wrappers, as they will be evaluated over all the criteria determined for the AHP method among the plants that grow naturally in İzmir and have the potential to be used in landscape studies in the literature (Table 2).

The study area, İzmir, is a city located in the west of Turkey and has a coast on the Aegean Sea (Figure 3). In addition, the city is the 3rd most populous city in Turkey with 4425789 people according to 2021 data. İzmir is in the Mediterranean climate zone and is open to the effects of the sea (Birdal et al., 2018; TÜİK, 2021).

Table 2. Plants that grow naturally in the Izmir region and can be used in landscape applications. (Davis, 1965; Bayraktar, 1980; Dikicioğlu, 2005; Güngör, 2012; Esener, 2018, Esener, 2019; Esener 2020a; Esener, 2020b).

No	Plant Species	Family	No	Plant Species	Family
1.	*Anchusa italica*	*Boraginaceae*	29.	*Marrubium vulgare*	*Lamiaceae*
2.	*Arbutus andrachne*	*Ericaceae*	30.	*Myrtus communis*	*Myrtaceae*
3.	*Arbutus unedo*	*Ericaceae*	31.	*Nerium oleander*	*Apocynaceae*
4.	*Asparagus acutifolius*	*Asparagaceae*	32.	*Olea europaea*	*Oleaceae*
5.	*Asphodelus microcarpus*	*Asphodelaceae*	33.	*Osyris alba*	*Santalaceae*
6.	*Berberis crataegina*	*Berberidaceae*	34.	*Paliurus spina-christi*	*Rhamnaceae*
7.	*Calicotome villosa*	*Fabaceae*	35.	*Papaver rhoeas*	*Papaveraceae*
8.	*Castanea sativa*	*Fagaceae*	36.	*Phillyrea media*	*Oleaceae*
9.	*Cercis siliquastrum*	*Fabaceae*	37.	*Pinus brutia*	*Pinaceae*
10.	*Cistus salviifolius*	*Cistaceae*	38.	*Pinus nigra*	*Pinaceae*
11.	*Cistus villosus*	*Cistaceae*	39.	*Pyrus amygdaliformis*	*Rosaceae*
12.	*Clematis cirrhosa*	*Ranunculaceae*	40.	*Pistacia lentiscus*	*Anacardiaceae*
13.	*Cyclamen neapolitanum*	*Primulaceae*	41.	*Pistacia terebinthus*	*Anacardiaceae*
14.	*Delphinium orientale*	*Ranunculaceae*	42.	*Platanus orientalis*	*Platanaceae*
15.	*Ephedra campylopoda*	*Ephedraceae*	43.	*Poterium spinosum*	*Rosaceae*
16.	*Equisetum arvense*	*Equisetaceae*	44.	*Prunus spinosa*	*Rosaceae*
17.	*Erica arborea*	*Ericaceae*	45.	*Pyracantha coccinea*	*Rosaceae*
18.	*Erica verticillata*	*Ericaceae*	46.	*Quercus rotundifolia*	*Fagaceae*
19.	*Hedera helix*	*Araliaceae*	47.	*Quercus coccifera*	*Fagaceae*
20.	*Hypericum cymbiferum*	*Hypericaceae*	48.	*Quercus pubescens*	*Fagaceae*
21.	*Hypericum empetrifolium*	*Hypericaceae*	49.	*Ranunculus orientalis*	*Ranunculaceae*
22.	*Jasminum fruticans*	*Oleaceae*	50.	*Rhus coriaria*	*Anacardiaceae*
23.	*Juniperus communis*	*Cupressaceae*	51.	*Ruscus aculeatus*	*Asparagaceae*
24.	*Juniperus foetidissima*	*Cupressaceae*	52.	*Salvia verticillata*	*Lamiaceae*
25.	*Juniperus oxycedrus*	*Cupressaceae*	53.	*Smilax aspera*	*Smilacaceae*
26.	*Juniperus phoenicea*	*Cupressaceae*	54.	*Spartium junceum*	*Fabaceae*
27.	*Laurus nobilis*	*Lauraceae*	55.	*Tamarix tetrandra*	*Tamaricaceae*
28.	*Lavandula stoechas*	*Lamiaceae*	56.	*Vitex agnus-castus*	*Verbenaceae*

Figure 3. The study area is Izmir.

The following methods were followed in the study, respectively;

1. Stage: AHP method was applied to rank the alternatives that can be used in vertical garden systems and to determine the most suitable species among the plants that grow naturally in İzmir and have potential use in landscape studies, which were determined by the literature review. Selection criteria have been determined to be evaluated in the AHP method. The selection criteria were determined by taking the geometric average of the expert opinions received from five authorized people who have done applications related to the characteristics of the plants used in vertical garden systems and vertical garden systems in the literature reviews. In the AHP method, the hierarchical structure of the selection criteria was created, pairwise comparison matrices of the criteria were established, weight values were calculated and consistency analyses were made.
2. Stage: After the consistency analysis, the result was below 0.1, and the TOPSIS method was adopted by following the flow chart in Figure 2. In the TOPSIS method, plants were scored equally from 4 criteria using 1-10 point intervals. For example, a plant may score low if it does not meet the first criterion, and receive a high score if it meets the second, third or fourth criteria. After the completion of the TOPSIS method, 10 plant alternatives that can be used in vertical garden

systems are listed as a result. Among these 10 plants, the most suitable plant species in the 1st place is also indicated.

3. Stage: After listing the plant alternatives and specifying the most suitable species among them, suggestions were made about the design compositions that could be created for the use of the plant in vertical garden systems. In order to contribute to the literature, suggestions have also been made in terms of evaluating the usability of other alternatives.

3. Results and Discussion

First of all, the AHP method was applied to rank the alternatives among the target plants and to reach the most ideal species.

In the first step of the AHP method, determining the most suitable plant species to be used in vertical garden systems among the plant species in Table 2 and listing the alternatives is stated as the problem definition. Following the definition of the problem, the characteristics of the plants used in vertical garden systems in the literature review (Benvenuti et al., 2016; López-Rodríguez et al., 2016; Şenol and Söğüt, 2017; Fernández-Cañero et al., 2018; Kahraman et al., 2018; Alkan, 2020; Gür, 2021; Gür and Erduran Nemutlu, 2021; Kahraman and Erman, 2021; Kalay and Sarıman Özen, 2021) and the opinions of five experts who have done applications related to vertical garden systems (Figure 4). The geometric mean of expert opinions was taken. As a result of this average, the final 4 criteria were determined.

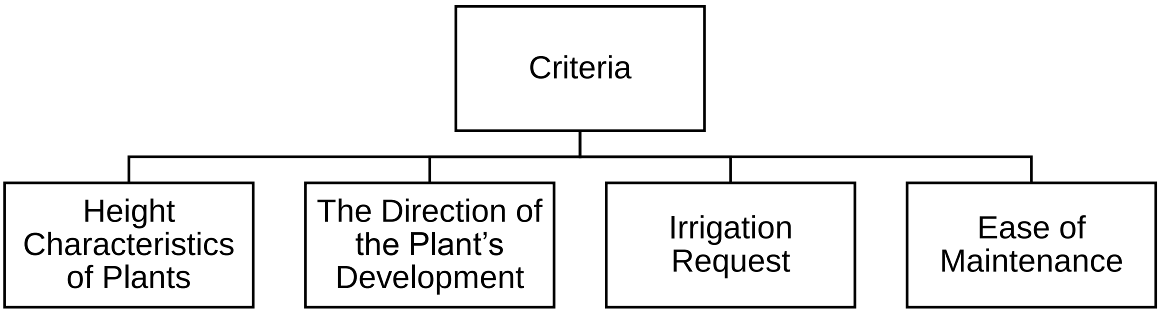

Figure 4. Hierarchical structure of criteria.

1. Criterion "Height Characteristics of Plants": Vertical garden systems have limited growing areas because they are applied on vertical surfaces. Plant height should not exceed 50 cm due to limited growing space.
2. Criterion “The Direction of the Plant’s Development": As plants develop in the growing environments in which they are placed, their development aspects should be relatively

inclusive. The plant should cover the growing area to provide visual integrity and make the image look more aesthetic.

3. Criterion "Irrigation Request": Irrigation is an important issue in vertical garden systems. Vertical gardens have both advantages and disadvantages in this issue. Good drainage is important as irrigation systems are not directed directly into the soil as in horizontal planes. At the same time, since it is applied to the building surface, irrigation should not damage the building surface. The water requirement of the plants to be used in the systems should be less compared to their use in the horizontal plane.
4. Criterion "Ease of Maintenance": One of the disadvantages of vertical garden systems is the difficulty of maintenance and maintenance costs. The plants to be used should be durable enough to be easy to care for and thus minimize maintenance costs.

After the selection criteria were determined and the hierarchical structure was created, the second stage of the AHP method, the pairwise comparison matrix, was started. The Saaty scale of 1-9 was used for comparisons, this matrix structure is shown in Table 3.

Table 3. The binary comparison matrix.

Criteria	Height characteristic of the plants	The direction of the plant's development	Irrigation request	Ease of maintenance
Height characteristic of the plants	1.00	5.00	6.00	3.00
The direction of the plant's development	0.20	1.00	0.25	0.33
Irrigation request	0.16	4.00	1.00	0.50
Ease of maintenance	0.33	3.00	2.00	1.00
Total	1.69	13.0	9.25	4.83

After the pairwise comparison matrix, the values in Table 3 were normalized. Table 4 shows the normalized pairwise comparison matrix.

After the second stage was completed, the average of the row sums of the normalized matrices was taken in the third stage of the AHP method. Thus, the weights of the criteria were calculated. This process is shown in Table 5.

After the criterion weights were calculated, step 4 was started. In this step, consistency analysis was performed and it was seen that the found consistency ratio was less than 0.1 (0.091314782). The fact that this value is less than 0.1 indicates that the pairwise comparisons are consistent and the selection criteria are correct. According to the results obtained, the TOPSIS method was used.

Table 4. Normalized Binary Comparison Matrix.

Normalization	Height characteristics of the plants	The direction of the plant's development	Irrigation request	Ease of maintenance
Height characteristics of the plants	0.591715976	0.384615385	0.648648649	0.620689655
The direction of the plant's development	0.118343195	0.076923077	0.027027027	0.068965517
Irrigation request	0.094674556	0.307692308	0.108108108	0.103448276
Ease of maintenance	0.195266272	0.230769231	0.216216216	0.206896552

Table 5. Criterion weights.

Criteria	Criterion weight
Height characteristics of the plants	0.561417416
The direction of the plant's development	0.072814704
Irrıgation request	0.153480812
Ease of maintenance	0.212287068

After the AHP method, the first step of the TOPSIS method was started. In the first step of the method, the decision matrix was created and shown in Table 6. Accordingly, the evaluation plants in the decision matrix were evaluated using scores ranging from 1 to 10 equally in all 4 criteria. Due to the high number of plants in Table 2, Table 6, Table 7 and Table 8 are shown in abbreviation in order not to repeat 56 plants continuously.

Table 6. Decision matrix.

No	Plant Species	Height characteristics of the plants	The direction of the plant's development	Irrıgation request	Ease of maintenance
1.	*Anchusa italica*	6	5	7	8
2.	*Arbutus andrachne*	1	3	6	5
3.	*Arbutus unedo*	2	3	5	6
4.	*Asparagus acutifolius*	7	7	5	7
	.				
	.				
27.	*Laurus nobilis*	1	9	7	7
28.	*Lavandula stoechas*	10	10	9	9
29.	*Marrubium vulgare*	10	8	7	6
30.	*Myrtus communis*	3	8	6	7
	.				
	.				
53.	*Smilax aspera*	1	3	6	6
54.	*Spartium junceum*	2	8	7	7
55.	*Tamarix tetrandra*	2	7	6	6
56.	*Vitex agnus-castus*	2	7	7	7

After the creation of the decision matrix structure, which is the first stage of the TOPSIS method, the second stage was started. At this stage, the normalization process is performed.

After the normalization process, a standard decision matrix was created. The standard decision matrix is shown in Table 7.

Table 7. Standard decision matrix.

No	Plant Species	Height characteristics of the plants	The direction of the plant's development	Irrıgation request	Ease of maintenance
1.	*Anchusa italica*	0.167248402	0.095207875	0.147770116	0.126238881
2.	*Arbutus andrachne*	0.028272964	0.049266464	0.131243592	0.091409053
3.	*Arbutus unedo*	0.034025614	0.034551299	0.111859343	0.120677698
4.	*Asparagus acutifolius*	0.198307445	0.102159849	0.111001534	0.141827157
27.	*Laurus nobilis*	0.026028960	0.138658590	0.122901623	0.110459021
28.	*Lavandula stoechas*	0.278747337	0.188545050	0.158016372	0.132124549
29.	*Marrubium vulgare*	0.278747337	0.148122752	0.115094846	0.088083033
30.	*Myrtus communis*	0.083624201	0.115027569	0.091255413	0.095612714
53.	*Smilax aspera*	0.027863911	0.059596115	0.133498248	0.124114321
54.	*Spartium junceum*	0.055727821	0.158922973	0.155747956	0.144800041
55.	*Tamarix tetrandra*	0.055727821	0.139057602	0.133498248	0.124114321
56.	*Vitex agnus-castus*	0.055727821	0.139057602	0.155747956	0.144800041

In the third step of the TOPSIS method, the standard decision matrix is transformed into a weighted standard decision matrix. For this process, criterion weights obtained from the AHP method were used. The weighted standard decision matrix is shown in Table 8.

Table 8. Weighted decision matrix.

Criterion Weights		0.561417416	0.072814704	0.153480812	0.212287068
No	**Plant Species**	**Height characteristics of the plants**	**The direction of the plant's development**	**Irrıgation request**	**Ease of maintenance**
1.	*Anchusa italica*	9.389616568	0.693253326	2.267987737	2.679888183
2.	*Arbutus andrachne*	1.587293457	0.358732299	2.014337304	1.940495985
3.	*Arbutus unedo*	1.910257224	0.251584263	1.716826272	2.561831468
4.	*Asparagus acutifolius*	11.13332533	0.743873915	1.703660558	3.010807137
	.				
	.				
27.	*Laurus nobilis*	1.461311164	1.009638419	1.886304086	2.344902161
28.	*Lavandula stoechas*	15.64936095	1.372885197	2.42524811	2.804833320
29.	*Marrubium vulgare*	15.64936095	1.078551435	1.766485035	1.869888880
30.	*Myrtus communis*	4.694808284	0.837569842	1.400595481	2.029734268
	.				
	.				
53.	*Smilax aspera*	1.564328470	0.433947347	2.048941948	2.634786521
54.	*Spartium junceum*	3.128656941	1.157192926	2.390432273	3.073917608
55.	*Tamarix tetrandra*	3.128656941	1.012543810	2.048941948	2.634786521
56.	*Vitex agnus-castus*	3.128656941	1.012543810	2.390432273	3.073917608

Using the matrix structure in Table 8, negative ideal and positive ideal solution points were created. In order to create ideal points, the highest and lowest values in the normalized matrix of the evaluation factor in the decision matrix were determined. These points are shown in Table 9.

Table 9. Creation of Ideal and Negative Ideal solutions.

	Creation of Ideal and Negative Ideal solutions			
Ideal Solution	17.41294967	1.372885197	2.731922597	3.513048695
Negative Ideal Solution	0.640335295	0.251584263	0.708456824	1.260108030

In the next stage of the method, the maximum distance to the ideal solution was calculated, and then the last stage of the TOPSIS method was started. In the last stage, among the alternatives, 10 plant species alternatives suitable for use in vertical garden systems are listed in Table 10, starting with the most ideal one.

Table 10. Weighted decision matrix.

Relative closeness to the ideal solution	
Lavandula stoechas	0.887765025
Hypericum cymbiferum	0.871635448
Marrubium vulgare	0.852314807
Equisetum arvense	0.818453519
Ruscus aculeatus	0.802291818
Salvia verticillata	0.798886781
Ranunculus orientalis	0.710206391
Cistus salviifolius	0.707742884
Papaver rhoeas	0.705194471
Osyris alba	0.684372655

It is the one suitable for use in vertical garden systems among the plant alternatives, which is in the 1st place in the ranking. As a result, the first plant species among the alternatives is *Lavandula stoechas* L. If we look at the studies on the morphological features and ecological demands of *Lavandula stoechas* L. in the literature, Bayraktar (1980), determined the plants that grow naturally in the Izmir region in his study and listed the species that can be used in landscape studies. Accordingly, in his study, he mentioned that *Lavandula stoechas* L. plant has a very low water demand, is resistant to sunny and dry areas, and has a high tolerance for soil. Based on this, he stated that this plant species is suitable for use in landscaping works in areas such as rock gardens that require low maintenance and provide limited growth space. If we look at the study, it has been seen that the plant will not have any problems growing in vertical garden systems. In another study, Yenici (1999), described the morphological features of *Lavandula stoechas* L. and talked about its ecological demands. Accordingly, he mentioned that the height of the plant is 45-50 cm and that it has a large diameter structure. He also stated in his study that this plant has a very high tolerance for thirst. Şahinler et al. (2022), in their study examining the importance of *Lavandula stoechas* L. plant in pharmacognosy and phytotherapy, stated that the plant can grow in almost any type of soil, including arid and not very acidic soils. This feature of the plant is very effective in terms of ease of care. In addition, it was stated in this study that the plant is tolerant of sunny and dry areas, so it is drought resistant. Considering these studies describing the *Lavandula stoechas* L. plant in general terms, it proves the accuracy of the results of the applied AHP and TOPSIS methods.

4. Conclusion

One of the biggest problems of the 21st century is migration from rural areas to urban areas and the negative effects of these migrations on cities. Population growth, increase in construction and the use of natural resources for energy adversely affect sustainability in the urban environment, urban biodiversity and urban ecology. Due to the construction in urban areas, especially urban open-green areas are affected. The decrease in urban open-green areas and the possibility of extinction threaten the population of natural vegetation, which is an important building block of urban biodiversity. The natural vegetation of the cities, geology, geomorphology and hydrogeology of the city show us very important descriptive information about the cities they are located in. For this reason, the use of natural plant species in cities in landscape designs and planning is very important in terms of urban biodiversity and sustainability. Since landscaping areas in cities are decreasing like urban open-green areas, the use of these natural species in alternative green areas such as vertical garden systems provides a good advantage in terms of sustainability. In the study, plants that naturally grow in İzmir, one of the important metropolitan cities of Turkey, and are potentially suitable for use in landscape studies, were determined and listed with the help of a literature review. AHP and TOPSIS methods, which are multi-criteria decision-making methods, were used to rank the plant species alternatives that allow them to be used in vertical garden systems among these determined species and to determine the most suitable one among these alternatives. It has been determined quantitatively that *Lavandula stroechas* L. is the most ideal species for use in this ranking. With this result, it has been revealed that *Lavandula stoechas* L. can be an alternative species that can be used in vertical garden systems. It can be used as a concealer in vertical gardens with its large diameter formation feature. As stated in the study, it can be used to create a background for places to be emphasized in vertical gardens with the image of the green leaves starting from the base of the plant and rising in large numbers. The widespread use of *Lavandula stoechas* L. plant in vertical gardens will benefit urban biodiversity, urban sustainability and protection of natural vegetation in all areas of the Mediterranean climate zone where the plant grows naturally.

Note

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